

Evaluating the Impact of Atmospheric Infrared Sounder (AIRS) Data On Convective Forecasts

Danielle Kozlowski¹ and Bradley Zavodsky²

¹University of Missouri, Columbia, MO

²NASA Marshall Space Flight Center, Huntsville, AL

The Short-term Prediction Research and Transition Center (SPoRT) is a collaborative partnership between NASA and operational forecasting partners, including a number of National Weather Service offices. SPoRT provides real-time NASA products and capabilities to its partners to address specific operational forecast challenges. One challenge that forecasters face is using numerical models that do not correctly predict mesoscale convective weather. In order to address this specific forecast challenge, SPoRT produces real-time mesoscale model forecasts using the Weather Research and Forecasting model (WRF-ARW) that includes unique NASA products and capabilities including information from the NASA 4-km Land Information System (LIS), NASA 1-km SPoRT SST analysis and NASA 1-km MODIS Greenness Vegetation Fraction (GVF) analysis, and retrieved thermodynamic profiles from the Atmospheric Infrared Sounder (AIRS), which are assimilated into the local SPoRT WRF model at 0900 UTC. AIRS is a sounding instrument aboard NASA's Aqua satellite that provides temperature and moisture profiles of the atmosphere. The SPoRT WRF was used in the Experimental Forecast Program (EFP) at NOAA's Hazardous Weather Testbed (HWT) during the Spring Experiment. Here it was analyzed by a broad spectrum of the scientific community including Storm Prediction Center (SPC) forecasters, National Weather Service (NWS) forecasters and research meteorologists. The goal of the HWT is to quickly transition meteorological technologies and advances in forecasting and warning severe weather events throughout the United States. This study was specifically designed to evaluate the impact of AIRS data on convective forecasts.

To evaluate the impact of AIRS profiles on the SPoRT WRF forecasts, a case study that covered the significant tornado outbreak across Central and Southeastern United States during the days of April 25-27, 2011, was examined. Three different forecasts were analyzed including the NSSL WRF, the SPoRT WRF and the SPoRT WRF without AIRS data. Radar reflectivities from these three forecasts were then verified against Q2 radar analysis data developed by NSSL. Differences between the simulated reflectivities were further investigated using variables that describe how conducive the atmosphere is for convective weather including convective available potential energy (CAPE), total precipitable water (TPW), helicity, convective inhibition (CIN) along with the model atmospheric soundings and observed soundings taken from AIRS. After analyzing these forecasts, initial results show that AIRS data do have an impact on the convective forecasts. However, a further in depth analysis will be needed to tell whether it was a positive or negative impact.

Evaluating the Impact of Atmospheric Infrared Sounder (AIRS) Data On Convective Forecasts

Danielle Kozlowski¹, Bradley Zavodsky²

¹ NASA Undergraduate Student Research Program, Huntsville, AL and University of Missouri Columbia, MO

² NASA Marshall Space Flight Center/Short-term Prediction Research and Transition (SPoRT) Center, Huntsville, AL

1. Introduction

The Short-term Prediction Research and Transition Center (SPoRT; Goodman *et al.* 2005) is a collaborative partnership between NASA and operational forecasting partners, including a number of National Weather Service (NWS) offices. SPoRT provides real-time NASA products and capabilities to its partners to address specific operational forecast challenges. The mission of SPoRT is to transition observations and research capabilities into operations to help improve short-term weather forecasts on a regional scale. Two areas of focus are data assimilation and modeling, which can to help accomplish SPoRT's programmatic goals of transitioning NASA data to operational users.

Forecasting convective weather is one challenge that faces operational forecasters. Current numerical weather prediction (NWP) models that operational forecasters use struggle to properly forecast location, timing, intensity and/or mode of convection. Given the proper atmospheric conditions, convection can lead to severe weather. SPoRT's partners in the National Oceanic and Atmospheric Administration (NOAA) have a mission to protect the life and property of American citizens. This mission has been tested as recently as this 2011 severe weather season, which has seen more than 300 fatalities and injuries and total damages exceeding \$10 billion (http://en.wikipedia.org/wiki/April_25%E2%80%9328,_2011_tornado_outbreak#April

_25). In fact, during the three day period from 25-27 April, 1,265 storms reports (362 tornado reports) were collected making this three day period one of most active in American history.

To address the forecast challenge of convective weather, SPoRT produces a real-time NWP model called the SPoRT Weather Research and Forecasting (SPoRT-WRF), which incorporates unique NASA data sets. One of the NASA assets used in this unique model configuration is retrieved profiles from the Atmospheric Infrared Sounder (AIRS). The goal of this project is to determine the impact that these AIRS profiles have on the SPoRT-WRF forecasts by comparing to a current operational model and a control SPoRT-WRF model that does not contain AIRS profiles.

2. Background

a. Hazardous Weather Testbed (HWT)

The NOAA Hazardous Weather Testbed (HWT) is located in Norman, OK and is comprised of the National Severe Storms Laboratory (NSSL), the Storm Prediction Center (SPC) and the NWS Oklahoma City/Norman Weather Forecast Office. The HWT is designed to quickly transition meteorological technologies and advances in forecasting and warning for severe weather events throughout the United States. The HWT's research focuses on understanding severe weather processes, developing weather observation technology, and

improving forecast tools, specifically on weather radar, hydrometeorology, and forecast and warning improvements. This collaboration increases understanding of hazardous weather environments across the United States and promotes the infusion of new science and technology into forecast operations. HWT's goals are well aligned with SPoRT's goals, making for a natural collaboration between the two groups and making the SPC an ideal partner for SPoRT.

Each spring since 2001, the HWT has sponsored programs that join modelers and operational forecasters to evaluate model performance and experimental products for convective forecasts (e.g. Coniglio et al 2009). In 2011, the HWT sponsored three programs: the Experimental Forecast Program (EFP), the Experimental Warning Program (EWP) and the GOES-R Satellite Proving Ground (GOES-R). Research modelers, product developers, and operational forecasters all took part in the 2011 activities. The work herein focuses on the EFP, which is focused on transitioning numerical modeling research to help improve hazardous weather watches and outlooks issued by the SPC. The EFP focuses on the impact of high-resolution, mesoscale models and products derived from these simulations on weather events ranging from 0 to 36 hours on spatial domains ranging from a few counties to the entire CONUS. SPoRT team members participated in the EFP and the SPoRT-WRF was evaluated as a deterministic model member at this summer's program.

b. NSSL and SPoRT WRF

NSSL regularly runs a version of the Advanced Research Weather Research and Forecasting (WRF-ARW) on a 4-km CONUS domain (hereafter referred to as the NSSL-WRF) (Kain et al. 2010) and is routinely used by operational forecasters at

the SPC. The WRF options for the NSSL-WRF are shown in Table 1 and are tuned towards parameterization schemes that are most useful for forecasting convection. The NSSL-WRF model is run daily at 00 UTC and produces hourly forecasts out to 36 hours. SPoRT has configured a real-time model that uses the same domain and physics and dynamics model options as the NSSL-WRF, but incorporate unique NASA products and capabilities to improve the initial and boundary conditions of the model (hereafter referred to as the SPoRT-WRF). The SPoRT-WRF includes information from the NASA 4-km Land Information System (LIS; Case et al. 2011), NASA 1-km SPoRT SST analysis and NASA 1-km MODIS Greenness Vegetation Fraction (GVF) analysis (Case et al. 2011), and AIRS retrieved temperature and moisture profiles (Chou et al. 2010).

The SPoRT-WRF is initialized each day using the 12-km North American Mesoscale (NAM) model as the initial conditions. The boundary conditions are updated every 3 hours using the same model forecast. The LIS information, SPoRT SSTs, and MODIS GVFs are all incorporated into the initial conditions at model initialization. Due to the timing of the AIRS observations, the retrieved temperature and moisture profiles are assimilated at 0900 UTC using the WRF-Var data assimilation system (Barker et al. 2004) with the 9-hour SPoRT-WRF forecast as the analysis background field. WRF-Var estimates the true state of the atmosphere by minimizing a cost function that statistically blends a previous forecast, observations, and their respective errors. The WRF-Var analysis with the AIRS profile data is then used to re-initialize the model to complete the 48-hour forecast. This methodology follows the successful technique for assimilation of AIRS retrieved profiles presented in Chou et al. (2010).

c. Overview of AIRS Retrieved Temperature and Moisture Profiles

Both AIRS and the Advanced Microwave Sounding Unit (AMSU) are aboard the Earth Observing System (EOS) polar orbiting Aqua satellite and have an early afternoon equatorial crossing time. AIRS and AMSU construct an integrated temperature and humidity sounding system for NWP and climate studies. AIRS is the first hyperspectral infrared radiometer designed to support the operational requirements for medium-range weather forecasting of the National Oceanic and Atmospheric Administration's National Center for Environmental Prediction (NOAA's NCEP) and other numerical weather forecasting centers (Aumann *et al.* 2003). Here, AIRS retrieved profiles are used within the framework of the operational model used by NOAA SPC in an attempt to improve convective forecasts by updating the model initial conditions.

AIRS is a hyperspectral grating spectrometer which measures the thermal infrared spectrum with 2,378 spectral channels covering the 3.75-4.59 μm , 6.20-8.22 μm , and 8.8-15.4 μm spectral regions with resolving power ranging from 1080 to 1590 (Tobin *et al.* 2006). AIRS has 15-km horizontal resolution footprints at nadir, relative to the AMSU with a 45-km footprint at nadir. To produce an AIRS retrieved profile, nine coincident AIRS footprints are blended with one AMSU footprint in a 3x3 coupling as illustrated in Figure 1 (Aumann *et al.* 2003). Because AMSU is a microwave sounder, it can see through clouds and coupling the infrared footprints from AIRS with a footprint from AMSU allows AIRS to observe in clear and partly cloudy scenes. However, it also has a negative impact because the resolution of AIRS profiles is reduced. AIRS can provide near-radiosonde-quality atmospheric

temperature and moisture profiles with the ability to resolve some small scale vertical features (Aumann *et al.* 2003).

A quality indicator (QI), P_{best} , is used to select the most favorable data from each profile for inclusion in the analysis product. Figure 2 shows the three-dimensional distribution of the AIRS profiles from the 0900 UTC 27 April 2011 analysis. In the figure, white regions indicate gaps in the data between successive AIRS orbital swaths and/or missing profiles due to a failure of the retrieval algorithm in dense overcast conditions. The black points represent the highest quality data, and each colored pixel represents the pressure level above which observations are assimilated. The pressure levels correspond to the level that AIRS scans down to, usually a thick layer of clouds. The red rectangle illustrates the bounds of the analysis domain. The AIRS retrieved profiles are assimilated as separate land and water soundings due to differences in sounding quality due to emissivity difficulties over land.

3. Methodology

There are many different factors that go into determining a good NWP forecast, and it varies depending on the type of meteorologist. Some of the factors that qualify a good forecast are occurrence, location, timing, orientation, and intensity. A good NWP forecast should include more than one of these factors. A research meteorologist may conclude that a forecast is good if it meets some statistical criteria, but operational meteorologists have different criteria for evaluating forecasts. Operational forecasters fall into two categories: outlook forecasters (e.g. SPC) and warning forecasters (e.g. NWS). These two sets of forecasters go about forecasting in very different ways. An SPC forecaster focuses more heavily on long-range severe weather forecasts; whereas, an NWS forecaster does

more nowcasting. Forecasters at the SPC focus mainly on forecasting severe weather for a more broad area across the entire country using probabilistic forecasts. Forecasters at NWS offices forecast severe weather for only their County Warning Area (CWA) for more imminent and specific warnings. Because there are different types of operational forecasters, the different factors that determine a good forecast varies depending on the forecaster's mission. For SPC forecasters, the most important factors for a good NWP forecast are location and intensity because SPC issues outlook guidance for a broad area over a multi-hour window (personal communication, Greg Dial, SPC). For NWS forecasters, the two most important factors that qualify a forecast as good is the timing and position of the storms because NWS focuses on nowcasting (personal communication, Brian Carcione and Chelly Amin, Huntsville, NWS). An additional challenge in subjectively evaluating NWP forecasts is that even multiple forecasters in the same weather service office may give different answers because everyone has their own definition of a good forecast.

Evaluating model performance can be a challenge. At one forecast hour, one model may best represent the convection, but a few hours later that same model may be the worst representation. Additionally, certain models may handle the intensity of the storms while another model better handles the position or timing of the storms. To evaluate the impact of AIRS data on convective forecasts, the SPoRT-WRF ("SPoRT" in the following discussion) forecast from April 25-27th, 2011 is compared to the NSSL-WRF ("NSSL" in the following discussion) and SPoRT-WRF with No AIRS forecasts ("No AIRS" in the following discussion). This time was selected because of both the meteorological and societal impact of this timeframe. The

forecasts were qualitatively evaluated using the criteria for good forecasts described above with a stronger emphasis towards the position, intensity, and timing of the storms as NWP forecasts might be used by NWS forecasters. Both forecasts are verified using against the Q2 radar analysis data developed by NSSL (<http://www.nssl.noaa.gov/projects/q2/tutorial/q2.php>). Each three day evaluation has a 36 hour forecast period that was broken down into one day forecasts in order to more closely analyze the severe weather parameters. Multiple severe weather parameters from all three models were analyzed at each of these times including CAPE, CIN, model radar reflectivity, precipitable water, helicity and atmospheric soundings.

4. Case Study Analyses

a. 25 April 2011: Midwest U.S. Convection

April 25th was the first day of the three-day severe weather outbreak for the southern United States. The SPC issued a moderate risk of severe weather, for three consecutive days centered over Arkansas through Tennessee. At 3:25 pm CDT (2025 UTC), the SPC issued a particularly dangerous situation (PDS) tornado watch for much of Arkansas and parts of Missouri, Oklahoma, Texas and Louisiana. As a result, the focus of the model evaluation for 25 April is over the region and approximate time of the PDS tornado watch (2100 UTC).

Overall, the total coverage and location of convective features within the reflectivity field is best depicted by the SPoRT-WRF (Fig. 3). Both the NSSL and No AIRS model runs miss the bulk of the convection in southwest Missouri while the SPoRT WRF correctly forecast the event. Also, the SPoRT run more accurately predicts the formation of the two squall lines in the

Oklahoma/Arkansas region, but had the storms moving a little too slow. In Fig. 4, the NSSL and No AIRS model forecasts show more convective available potential energy (CAPE) than the SPoRT forecast, which should reduce the potential to produce more model reflectivity; however, the SPoRT-WRF produces higher reflectivity than the other two models that have larger CAPE values. Just before the AIRS data are assimilated at 0900 UTC, all models produce the same amount of CAPE across the region. However, at 0900 UTC the SPoRT run decreases the amount of CAPE in the atmosphere over Missouri, Oklahoma and Arkansas, the area of interest for this case study. Just because the NSSL and the No AIRS models have more CAPE to work with does not necessarily mean they will produce more convection. CAPE just measures the potential for severe weather; it does not mean that the model has to produce any amount of severe weather. The No AIRS model stays very similar to the NSSL model, which indicates that out of the four unique NASA data sets added, AIRS has the biggest impact on the forecast. The SPoRT WRF has a cooler more moist sounding (Fig. 5), which likely the result of the model already precipitating in that region. Although the NSSL and No AIRS model forecasts had a more convective sounding (Fig. 5) and more CAPE, they failed to produce convection in the correct area.

b. 26 April 2011: South U.S. Convection

A high risk of severe weather was issued for April 26 between 1200 and 1300 UTC by the SPC for portions of Louisiana, Arkansas, Oklahoma and Texas as conditions became even more favorable for extreme weather. Another PDS tornado watch with very high tornado probabilities was issued that afternoon for that same area (SPC, 6). Even though the higher potential for severe weather threat was located within

the PDS watch, Alabama was still going to experience severe weather as well, just later on in the day. Alabama was selected as the focus region for this day because severe weather was expected in this region, and because the model differences were largest here. Sure enough, many parts of Alabama experienced tornado and severe wind reports on this day.

All models correctly forecast the mode and timing of the precipitation, but not the intensity. The NSSL and SPoRT runs forecast convection nearly perfect for the first fourteen hours of the forecast, but at 1500 UTC the model radar reflectivities begin to deviate. At this time, the reflectivity over Alabama disappeared in the SPoRT run; however, the reflectivity in the NSSL and No AIRS forecasts indicated a strong convective squall line. The Q2 observed reflectivity at 1500 UTC shows some light to moderate precipitation over central Alabama in a linear feature, but does not show much in the way of intense convection at this time (Fig. 6). All three models do a poor job of forecasting the event after 1500 UTC. Over central Alabama, both the NSSL and No AIRS runs have nearly 2500 J/kg CAPE with little convective inhibition (CIN), which is most likely what helped form the large convective line of storms across Alabama. The SPoRT run has less CAPE (Fig. 7) than the other two models and a stronger temperature inversion (Fig. 8) which would suppress convection in the model forecast. The SPoRT run also has the driest sounding of the three models, which also acts to reduce the convection. The NSSL and No AIRS atmospheric soundings have smaller inversions and higher moisture, which makes them more conducive for convection (Fig. 6). At 0900 UTC the SPoRT WRF with AIRS data assimilated decreases the amount of CAPE of the region of interest, northern Alabama. The NSSL and the No

AIRS models are very similar in the CAPE fields again as they were in the 25th case study. There wasn't a change in the model reflectivity until sometime between 1200 and 1500 UTC, where all three models have difficulty forecasting the event.

c. 27 April 2011:North/Central AL Convection

On Wednesday April 27, 2011 conditions were ripe for a disastrous severe weather outbreak in the southeast United States, the main target being northern and central Alabama. The Storm Prediction Center (SPC) had been monitoring this potential severe weather outbreak for several days, knowing that it would most likely be a high risk day. On top of this, the previous days April 25-26 were also severe weather days for the south and southeast, with the 25th being a slight risk and the 26th a moderate risk, changing to a high risk. On 27 April, northern Alabama had been forecasted under a moderate risk from the day 3 outlook. By 1200 UTC for the Day 1 outlook is when it was upgraded to a high risk day. The last 24 hour period with the most tornadoes recorded was April 3-4, 1974 with 148 tornadoes. According to NOAA, 340 people lost their lives over the 24 hour period from 1300 UTC on the 27th to 1300 UTC on the 28th (http://www.noaa.gov/factsheets/new%20version/Tornadoes_web_version_final.pdf). This would be the deadliest single day for tornadoes since March 18, 1925 tornado outbreak. The 27 April outbreak over Alabama was comprised of three waves of storms. From 0700 UTC to 1300 UTC is when the first round of storms hit northern Alabama. This convective weather was classified as a quasi-linear convective system (QLCS) with the main threat being damaging winds and isolated tornadoes. The second wave of severe weather was partly

the remains of the QLCS that had pushed through earlier that morning; however, this started to break up into more discrete cells. From 1930 UTC onward, a massive tornado outbreak of classic supercell thunderstorms occurred across parts of eastern Mississippi, northern and central Alabama, southern Tennessee and northern Georgia, which would prove to be the most severe round of storms all day. The analysis herein focuses on the third (and most significant) of these waves.

All three models predicted the significant severe weather outbreak, but none forecasted the exact location and track of the super cells. This is an example of a good forecast when verified from an outlook standpoint (SPC), but not when verified from a warning standpoint (NWS). At 0000 UTC on 28 April (24-hour forecast), the Q2 observations show two distinct sets of supercell lines over northern and central Alabama. Both the NSSL and No AIRS runs forecast the northern line of severe super cells that tracked through Alabama, but missed the southern line of convection (Fig. 9). The SPoRT run seems to forecast the southern line of storms, but misses the northern line.

The CAPE fields indicate that the much of Alabama has high CAPE values in the NSSL and No AIRS runs, but the SPoRT run shows reduced CAPE over much of the state. Additionally, the main CAPE gradient, which is most likely associated with the cold front is pushed further to the south in the SPoRT run (Fig. 10). The sample model soundings from Northeastern Alabama for the NSSL and No AIRS are very similar with saturated and unstable conditions. However, the SPoRT model sounding exhibits a saturated yet more stable sounding, which is likely associated with the model precipitating. Further investigation into the sounding reveals that the SPoRT run has lower-level winds out of the northwest;

whereas, the NSSL and No AIRS runs still have lower-level winds from the south. These wind patterns indicate that the SPoRT run has pushed the cold front past the sounding location, and the NSSL and No AIRS runs still have the cold front over northwestern Alabama. In reality, the cold front at 0000 UTC was still over northeastern Mississippi (see Fig. 9). As a result, it appears that the SPoRT run has the front moving through the area about three to four hours too soon. The line of convection that matches the southern line of supercells that seems well-represented in the SPoRT run actually is an artifact of the misplacement of the cold front. Thus, the SPoRT run places storms in the proper location, but for the incorrect reason. The NSSL and No AIRS runs place the cold front closer to the actual location, but miss the strong convective super cells that developed out ahead of the front. The reasons for this difference in frontal speed will be evaluated in future work.

5. Conclusions and Future Work

Over the three-day span from 25-27 April 2011, a wide variety of strong supercell storms produced a wide variety of tornadic storms. This super outbreak broke multiple records, making it the worst tornado outbreak in the southeast U.S. since 1974. After evaluating the NSSL, SPoRT, and No AIRS model forecasts from the 25-27 April tornado outbreak, results indicate that adding AIRS profiles into the SPoRT WRF has an impact on convective forecasts. On 25 April the SPoRT WRF forecasts convection better in southwest Missouri and the two squall lines that formed in both Oklahoma and Arkansas. During 26 April, the SPoRT-WRF correctly under-produced model reflectivity when compared to the observed Q2 NSSL reflectivity and the NSSL and No AIRS model runs. Lastly, on

27 April, the SPoRT-WRF forecasts the cold front passing through about 3 to 4 hours too fast, which produces the correct amount of convection and in the general area but for the wrong meteorological reasons. Therefore, one of the key ingredients for models to correctly predict convection is the speed and position of frontal boundaries. Although this case study gives more insight into how numerical weather models handle predicting convection, it does not show enough evidence to determine which model handles severe weather forecasting the best. Additional analyses will be needed to determine whether the impact from adding AIRS profiles is positive or negative on convective forecasts.

6. Acknowledgements

Thanks to the Undergraduate Student Research Program (USRP) for funding my summer 2011 research at NASA's Marshall Space Flight Center. Special thanks to Mona Miller and Tina Haymaker at the Marshall Space Flight Center Education Office for their coordination of the Undergraduate Student Research Program.

Thanks to Hayden Oswald and Jordan Bell from the University of Missouri, for their support, encouragement and collaboration during this summer's internship. Lastly, I would like to thank Brad Zavodsky whose has been my mentor for these past two summers at NASA. He has helped me acquire the research and scientific writing skills that will help me in my graduate studies and in my professional career.

7. References

- Aumann, H. H., M. T. Chahine, C. Gautier, M.D. Goldberg, E. Kalnay, L. M. McMillin, H. Revercomb, P. W. Rosenkranz, 2003: AIRS/AMSU/HSB on the Aqua Mission: Design, Science Objectives, Data Products, and Processing Systems. *IEE Trans. On Geosci. And Rem. Sens.*, 41 (2).
- Barker, D.M., W. Haung, Y-R. Guo, A. J. Bourgeois, and Q.N. Xiao, 2004: A Three-Dimensional Variation Data Assimilation System for MM5: Implementation and Initial Results. *Mon. Wea. Rev.*, 132, 897-914.
- Case, J. L., F. J. LaFontaine, S. V. Kumar, and G. J. Jedlovec, 2011: A real-time MODIS vegetation composite for land surface models and short-term forecasting. *15th Symp. on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans and Land Surface*.
- Chou, S.-H., B. T. Zavodsky, G. J. Jedlovec, 2010: Regional Precipitation Forecasts with Atmospheric Infrared Sounder (AIRS) Profile Assimilation. *11th WRF User's Conference*, Boulder, CO. P-88.
- Chou, S-H, B. T. Zavodsky, and G. J. Jedlovec, 2010: Impact of Atmospheric Infrared Sounder (AIRS) Thermodynamic Profiles on Regional Weather Forecasting. *AMS 17th Conference on Satellite Meteorology and Oceanography*, Annapolis, MD.
- Coniglio, M. C., K. L. Elmore, J. S. Kain, S. J. Weiss, M. Xue, and M. L. Weisman, 2009: Evaluation of WRF model forecasts of environmental parameters for severe-weather forecasting from the NOAA HWT Spring Experiments. Preprints, 13th Conference on Mesoscale Processes, Amer. Meteor. Soc., Salt Lake City, UT, paper 5.1.
- Goodman, S. J., W. M. Lapenta, G. J. Jedlovec, J. C. Dodge, and T. Bradshaw, 2004: The NASA Short-term Prediction Research and Transition (SPoRT) Center: A collaborative model for accelerating research into operations. *Preprints, 20th Conference on Interactive Information Processing Systems (IIPS)*, Seattle, WA, Amer. Meteor. Soc., CD-ROM, P1.34.
- Kain, J. S., S. R. Dembek, S. J. Weiss, J. L. Case, J. J. Levitt, and R. A. Sobash, 2010: Extracting unique information from high-resolution forecast models: Monitoring selected fields and phenomena every time step. *Wea. Forecasting*, 25, 1536-1542.
- Tobin, D. C., H. E. Revercomb, C. C. Moeller, and T. S. Pagano, 2006: Use of Atmospheric Infrared Sounder high-spectral resolution to assess the calibration of Moderate resolution Imaging Spectroradiometer on EOS Aqua. *J. Geophys. Res.*, **111**.

Table 1. Model configuration for real-time NSSL WRF available to the SPC and select NWS offices.

Version	3.1.1
Dynamic	Advanced Research WRF (ARW)
Horizontal Grid Size	908 x 750
Vertical Levels	35
Horizontal Grid Resolution	4 km
Initial and Lateral Boundary Conditions	NCEP Eta 212 grid
Computational Platform	SGI Altix 4700 (64 processors)
Simulation Length	36 hours
Time Step	24 seconds
Cloud Microphysics	WSM6 Scheme
Shortwave Radiation	Dudhia Scheme
Longwave Radiation	RRTM Scheme
Land Surface Physics	Noah Land-Surface Model
PBL Physics	MYJ Scheme
Scalar Advection	Positive Definite

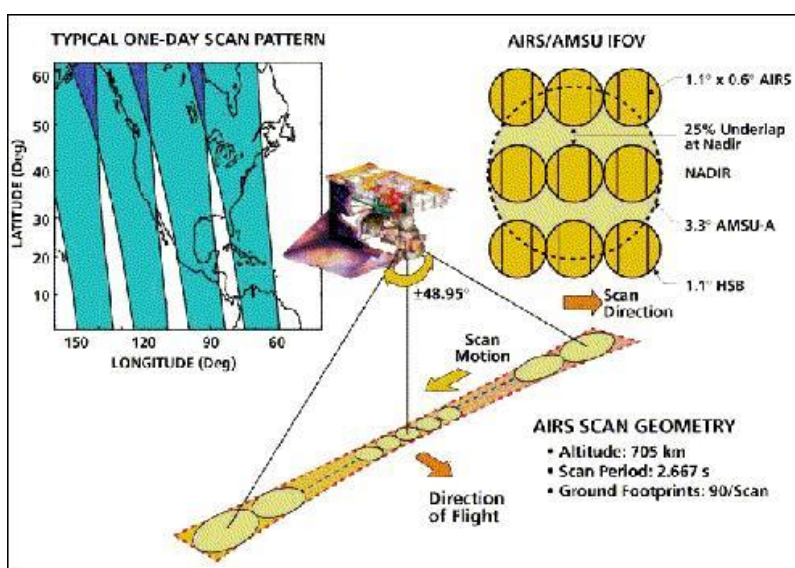


Fig. 1. Overview of AIRS instrument showing a typical one-day scan pattern, the scan geometry, and a graphical representation of the AIRS retrieved profile from one microwave AMSU footprint and nine infrared AIRS footprints.

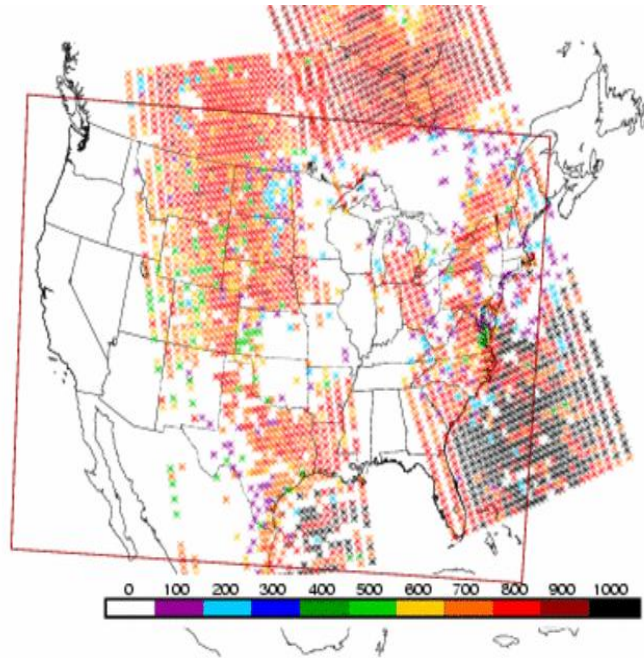


Figure 2. P_{best} (hPa) for AIRS profiles assimilated at 0900 UTC on 27 April 2011. Black points represent the highest quality data; white regions indicate data gaps due to clouds.

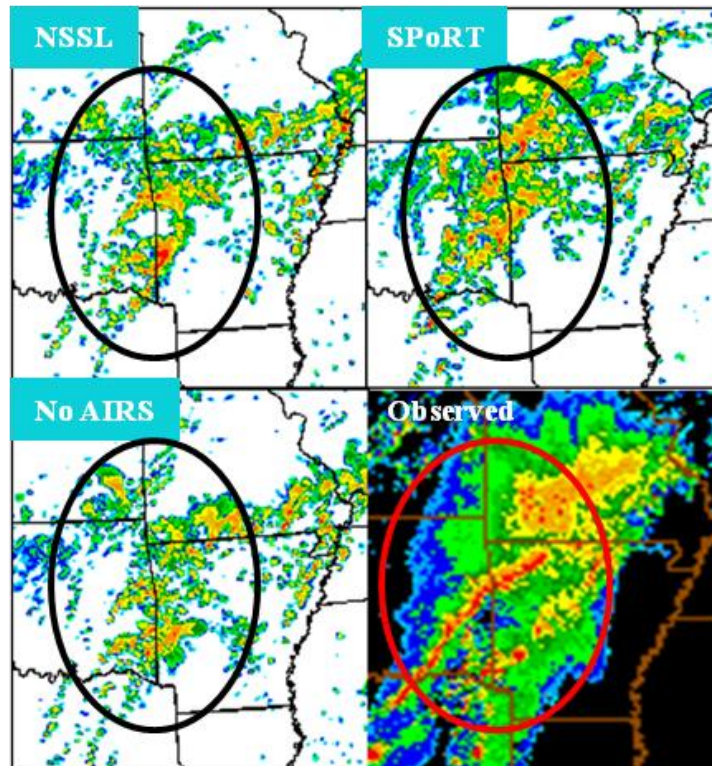


Figure 3. WRF model and observed reflectivity from 21-h forecast valid at 2100 UTC on 25 April 2011.

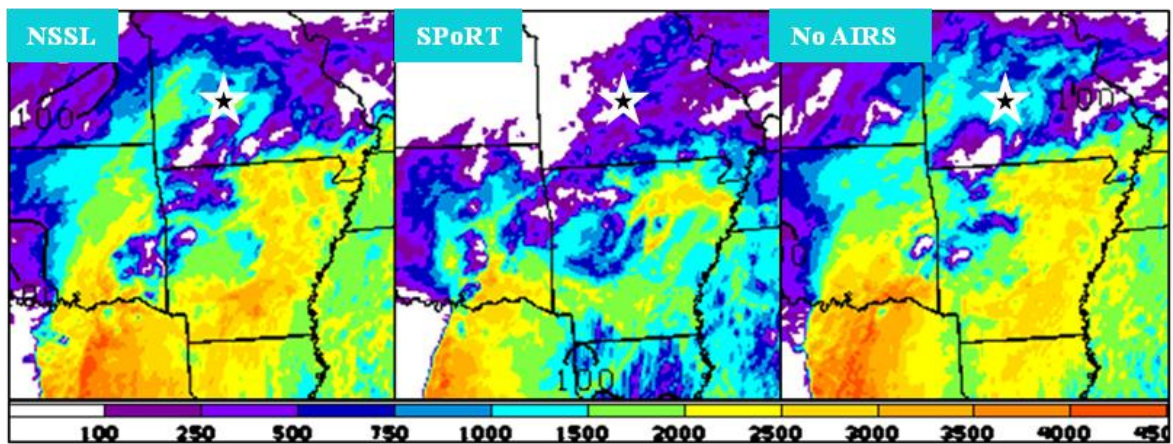


Figure 4. Most unstable CAPE (filled) and CIN (contoured) for 21-h forecast valid at 2100 UTC on 25 April 2011.

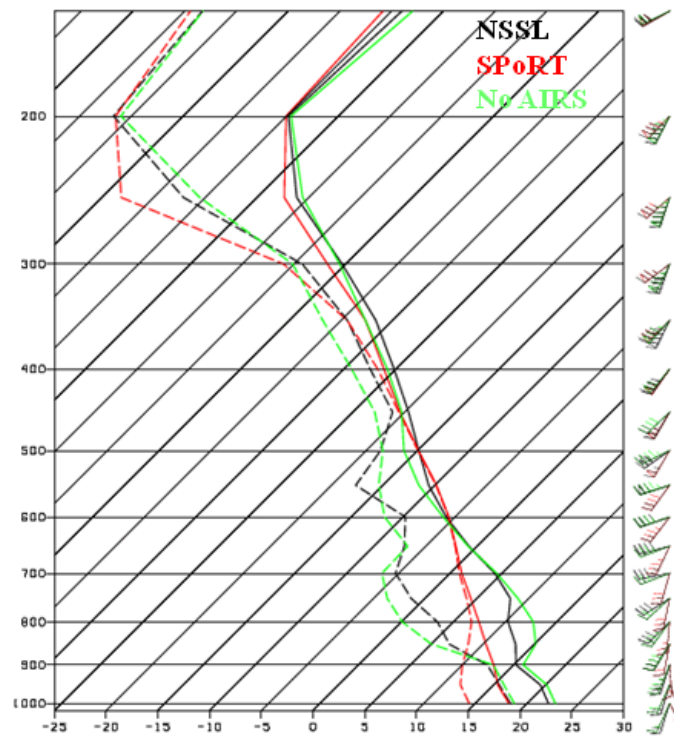


Figure 5. Skew-T plot for 21-h forecast valid at 2100 UTC on 2 April 2011 located 37.5 N, -93.0 W (stars in Fig. 3).

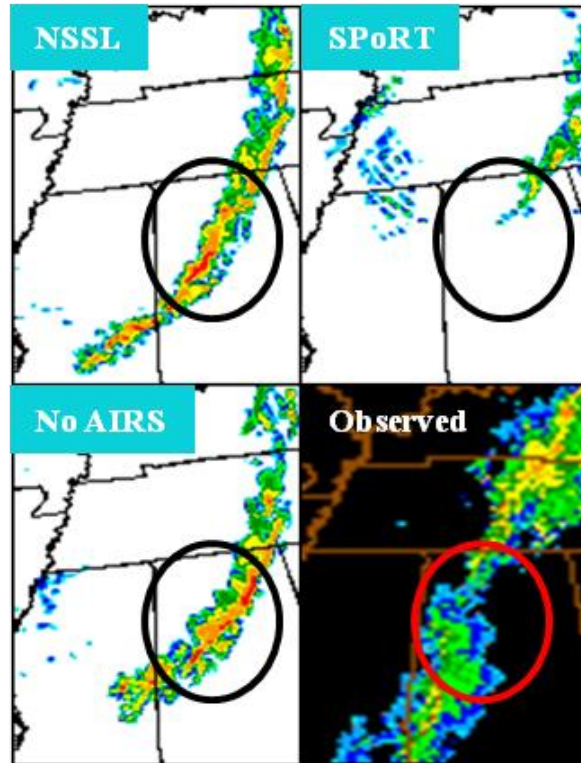


Figure 6. WRF model and observed reflectivity from 15-h forecast valid at 1500 UTC on 26 April 2011.

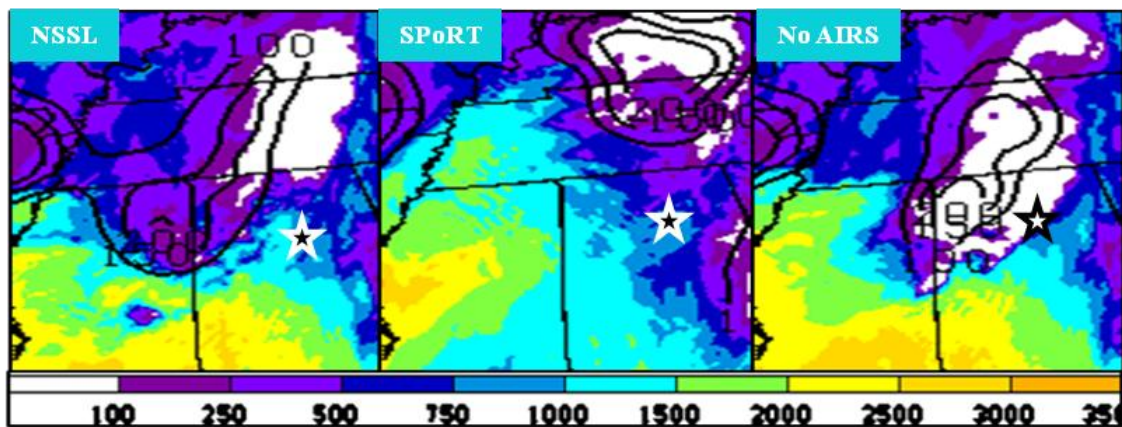


Figure 7. Most unstable CAPE (filled) and CIN (contoured) for 15-h forecast valid at 1500 UTC on 26 April 2011.

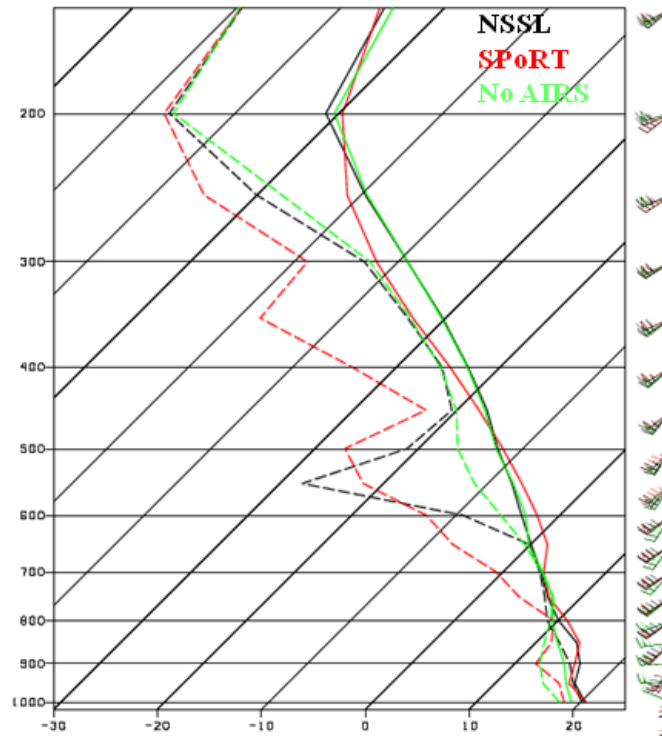


Figure 8. Skew-T plot for 15-h forecast valid at 1500 UTC on 26 April 2011 located at 34.0 N, -86.5 W (stars in Fig. 6).

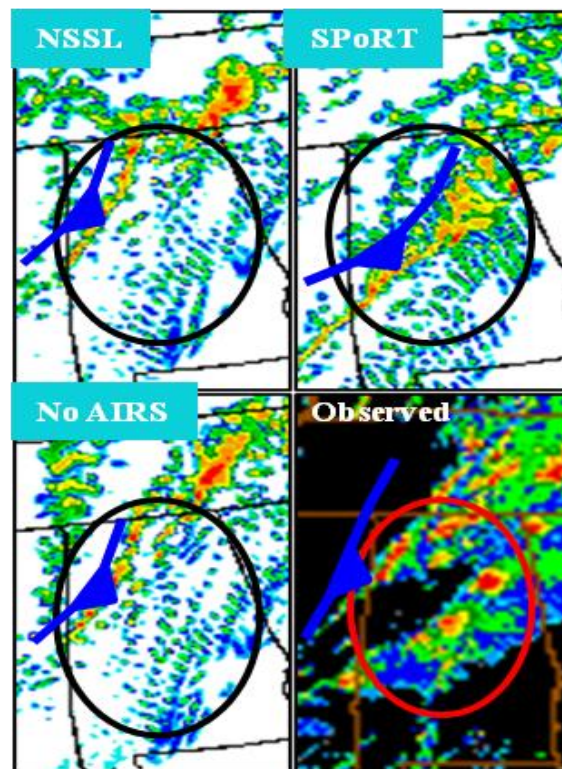


Figure 9. WRF model and observed reflectivity from 24-h forecast valid at 00 UTC on 28 April 2011 (shortly after EF-5 tornado hit Madison County, AL). Cold fronts are shown for each model and the actual placement of the cold front at 00 UTC. The NSSL and the No AIRS models had the front a bout 1-2 hours too fast while the SPoRT model had the front about 3-4 hours too fast.

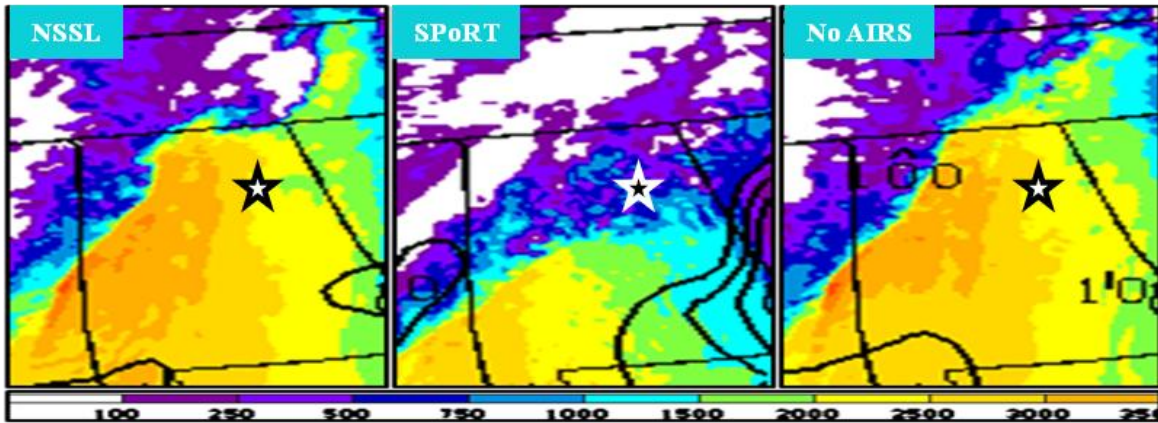


Figure 10. Most unstable CAPE (filled) and CIN (contoured) for 24-h forecast valid at 0000 UTC on 28 April 2011.

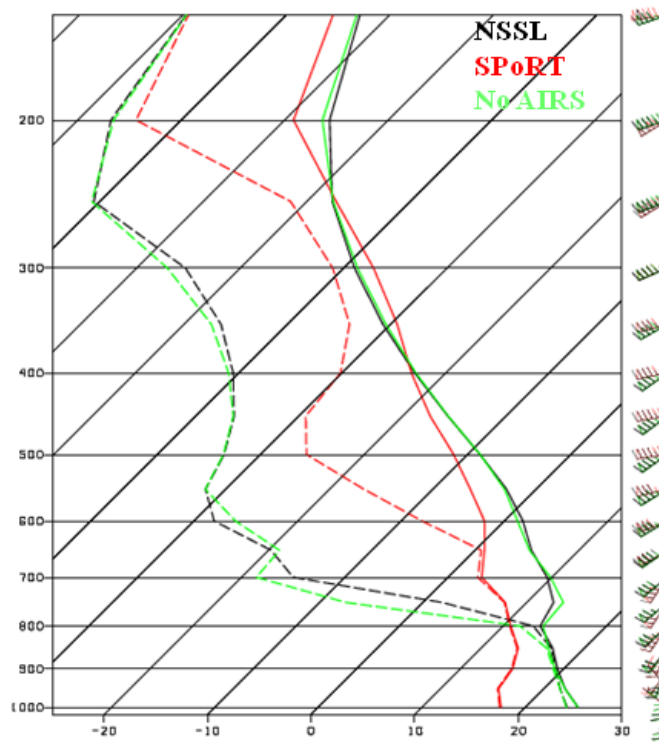


Figure 11. Skew-T plot for 24-h forecast valid at 0000 UTC on 28 April 2011 located at 33.5 N, -86.5 W (stars in Fig. 9).